CHAPTER 7
CONCLUSIONS

This study has assessed emission load of carbonaceous aerosols from agricultural residues open burning in Thailand. Emission loads of carbonaceous aerosols from agricultural residues open burning have been reviewed to investigate order of magnitude of carbonaceous aerosol emission factor (EF), including contribution of black carbon (BC) and organic carbon (OC) from global sources and share of agricultural residues open burning source.

From the literature review, EFs of carbonaceous aerosols were quantified by field experiment and chamber experiment. Measurement of the EF in this study was developed by emission concentration measurement from field experiment and chamber experiment.

The research has developed field experiment sampling method to determine quantity of biomass load (BL) or fuel of open burning in agricultural field. Emission inventory of the emission loads from agricultural open burning have been developed from agricultural open burning in Thailand integrating experimental, statistical, and remote sensing data. Information that serves for emission inventory consist of BL, fraction of biomass burned after utilization, combustion efficiency, area burned, and EF.

This study has developed methodology for quantifying BL in rice, corn, and sugarcane field, including methodology for measuring emission concentration to estimate EF of aerosols and key greenhouse gases from open burning of rice, corn, and sugarcane.

7.1 Biomass Load

Finding of BL in this study consists of methodology to sampling agricultural residues in the field, quantity of BL specific to rice, corn, and sugarcane residues in Thailand, and influence parameters on BL. Suitable sampling area to quantify BL of agricultural residues to represent the whole plot for rice, corn, and sugarcane is developed. Field experiments assess fuel from agricultural field burning and report BL values of rice straw, corn residues, and sugarcane leaves are 421±236, 610±153, and 1,007±95 g/m^2, respectively.

Influence parameters on BL of agricultural residues are period of rice growing, location of rice and sugarcane cultivation. Rain-fed paddy field cultivates longer period than irrigated paddy field so the BL is larger and has consequence on large emission load in the same area size as irrigated. Therefore, BL is classified into irrigated paddy field 360±140 g/m^2 and rain-fed paddy field 507±305 g/m^2. One reason of high variation in BL is because of difference in stubble height. Type of rice has also influence on BL in that different BL is found from different rice types that have been traditionally cultivated in each cycle at the studied site in Samutsakhon. The BL of the same crop type but cultivated in different place is different i.e. rice type Khao-Dok-Mali 105 BL in Amphoe Thatako is 410±255 g/m^2 but in Amphoe Mueang is 732±397 g/m^2; corn type 919 BL in Nakhonratchasima is 651±210 g/m^2 but in Nakhonsawan is 520±66 g/m^2; sugarcane type K88-92 BL in Kanchanaburi is 1,243±262 g/m^2 but in Chonburi is 692±151 g/m^2.

The average BL of rice in this study is compared with international statistics and found that the results of BL rice in this study are in the same range as IPCC (2006), BL of corn in this study is lower than other countries that were estimated by Jenkins et al. (1996) and IPCC (2006), and BL of sugarcane is higher than IPCC (2006).

Table 7.1 Compare biomass load with IPCC 2006

Biomass type	BL (ton/ha) IPCC, 2006	BL (ton/ha) this study
Rice	5.5	4.21±2.35
Maize	10	6.10±1.52
Sugarcane	6.5	10.07±2.95

The average BL of field experiment results in this study are further used for emission inventory of Thailand because they originate from field experiment specific to crop type in Thailand.

7.2 Agricultural Burned Area

Finding of biomass subjected to burning consists of area based and quantity based. The area based is determined by remote sensing data that provides temporal and spatial distribution of agricultural fires. Rice and sugarcane are mostly burned in central and northeast region of Thailand. Corn fire is mainly found in north and central region of the country. The agricultural fires are high in dry season, especially in February, and low in wet season during May to

September. Area based is also determined by ground based from national agricultural statistic data and percentage of burned area from literature review. The analysis provides trend and ranking of agricultural burned area. Trend of burned area in rice field is slightly increasing because increasing of harvested area for 1.5% from 1998 to 2007, especially in irrigated area that is cultivated more frequently. Burned area of corn is decreasing because of land use change. Burning in corn field is sometimes from alternative crop i.e. sunflower. Sugarcane field is increasing due to renewable energy promotion by the government. Burning of sugarcane area is increased because of the lack of harvest labor.

In agricultural year 2007, total burned area was 4.65 million ha, 84% was rice field (3.90 Mha), 13% was sugarcane field (0.61 Mha); and 3% was corn field (0.14 Mha). These values were applied to determine emission inventory from agricultural sector of Thailand.

7.3 Emission Factor

This study conducted real-time measurements of BC, CO, CO_2, and $PM_{2.5}$ to measure emission concentration from rice, corn, and sugarcane residues open burning in the field and in the simulated open burning chamber.

The disadvantage of EF calculated from field experiment consists of influence from surroundings and biomass condition, including the measurement cannot keep in the plume all the time. From filed open burning observation from real situation in the field, it was found that calm wind was mainly present. Therefore, the chamber was built to burn biomass without any air force, but open on one side of the chamber to let air into burning zone. Sampling inlets of the air samples were located close together to get the same air mass.

The result of experiment in the chamber is selected to apply in considering emission inventory of agricultural residues open burning in this study. The result of EF calculated from emission concentration measurement in the chamber experiment is consistent with other studies. Thailand specific EF is generated for rice straw, corn residues, and sugarcane leaves. The EF from this study can improve limit uncertainty of EF at a level from recent EF that is estimated by best guess as mentioned by Andreae and Merlet (2001).

Carbon balance of agricultural burning is considered and it is found that more than 90% of carbon from agricultural residues are released into the air, which ~90% of carbon released is in form of CO_2 that is consistent with EF_{CO2} from field experiment.

7.4 Carbonaceous Aerosol

Global sources of carbonaceous emission load are from two major sectors: biomass burning and fossil fuel combustion. The carbonaceous aerosol is determined by combination method between thermal method and real-time measurement. Thermal method is used to analyze %TC. However, aerosol from total filtration sampling is lower for 100 times of $PM_{2.5}$ due to sampling method so the $PM_{2.5}$ concentration from real time measurement in the field is used to quantify TC concentration. The disadvantage of thermal method is that it cannot separate organic carbon due to the carbon released at low temperature can become char that will be classified as BC and cannot be detected by this method. To overcome this problem, real time measurement is applied by using Micro Aethalometer to measure BC concentration. The result shows that main carbonaceous aerosol is from rice, the second is corn, and the third is sugarcane open burning, respectively.

7.5 Emissions Inventory

Agricultural based year of the inventory is 2007 due to availability of agricultural statistic data. Major source of emission load from agricultural open burning in the field is rice residues open burning that accounted for 71% BC, 69% CO_2, 71% CO, and 76% $PM_{2.5}$. The significant source is located in central region of Thailand, especially irrigated paddy area. The second source of emission load from agricultural open burning in the field is sugarcane, which share for 25% BC, 27% CO_2, 27% CO, and 23% $PM_{2.5}$. Share of emission load from corn field is so small 3% BC, 4% CO_2, 2% CO, and 1% $PM_{2.5}$, which are less than 5% and negligible.

Release of CO_2 in agricultural field is expected to be neutral because it can be sunk into the biomass by the next cultivation. Significant pollutants from agricultural sector are aerosols and CO. The aerosol emission load is a significant regional problem among countries, especially in dry season. The share of CO from biomass burning compare with all global sources is 32%, and contribution of BC from biomass burning in all sources at global level is >86%, which are significant (Andreae, 1991). The share of CO from agriculture in this study is accounted for 2.50% of total sources in Thailand (Vongmahadlek et al., 2009).

7.6 Recommendations

1) High standard deviation is found in results of BL and EF in this study because the initial phase lacks knowledge in methodology to quantify these values, so less uncertainty is expected to improve the value to estimate emission load from agricultural open burning in Thailand by sampling biomass in suitable areas that can represent the whole plot. It is necessary to invent or design measurement method or equipment to measure homogenous plume and keep in the plume all the period of burning.

2) Trend of emission load from sugarcane field is increasing, but there is no field experiment in this study because installation equipment in this study is 1.5 m at ground level, so it cannot detect the emission load from sugarcane field that releases at higher than around 4 m – because burning is done before harvesting on standing sugarcane tree 2-3 m height. Apparatus design is required to be able to bring the probe inside the plume at downwind. However, the sugarcane field is large so downwind distance is quite far and cannot move to keep in the plume during wind direction change.

3) Results of burned area estimated by remote sensing in this study are under estimation, so in the next study, estimation of burned area by remote sensing can be improved by using higher resolution of remote sensing data i.e. burned scar data from LANDSAT and focus the scope of the study in a small area.